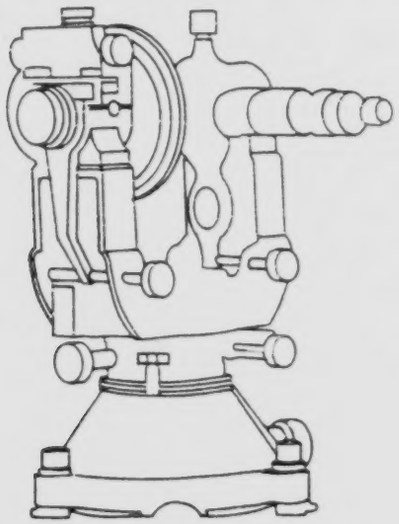
412-051-6782-A

MEASURE LEVEL VALUES FOR T-3 THEODOLITE (WISCONSIN METHOD)

TEC LESSON 412-051-6782-A



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PRODUCED BY
UNITED STATES ARMY
ENGINEER SCHOOL
FORT BELVOIR, VIRGINIA

STUDENT/SUPERVISOR INSTRUCTIONS, PRETEST/ POSTTEST, AND ANSWER KEY ARE CONTAINED IN THIS BOOK

SEPTEMBER 1985

D101.6/7:

If you have questions or comments concerning this TEC Lesson, address them to.:

Commandant
U.S. Army Engineer School
Attn.: ATZA-TD-I-E*
Fort Belvoir, VA 22060-5291

*Current symbol may be obtained from DA PAM 350-100, Appendix C.

READ THE STUDENT/SUPERVISOR INSTRUCTIONS CAREFULLY. BE SURE YOU UNDERSTAND THEM COMPLETELY BEFORE BEGINNING THE LESSON. PLEASE DO NOT WRITE IN THIS BOOK.

READEX FICHE

The words "he", "his", and "men", when used in this publication, represent both the masculine and feminine genders, unless otherwise specifically stated.

STUDENT/SUPERVISOR INSTRUCTIONS

TYPE OF LESSON:

- T-3 Theodolite

AUDIENCE:

- MOS 82D
- Skill Level 2

TRAINING OBJECTIVES:

Soldiers completing this lesson should be able to:

- Observe bubble readings for the determination of "d"
- Prepare instrument for calibration
- Check field notes

MATERIAL/EQUIPMENT/PERSONNEL REQUIRED:

- Printed text lesson —
- Pencil
- T-3 with tripod (optional)
- Recorder (optional)

TIME REQUIRED:

- Individual, 90 minutes
- Group, 120 minutes

REFERENCE:

- STP 5-82D 1/2/3/4 Topographic Surveyor
- TM 5-232 Elements of Surveying
- TM 5-442 Precise Astronomic Surveys

STUDENT/SUPERVISOR INSTRUCTIONS

STUDENT INSTRUCTIONS:

- Prerequisites: None
- Take the Pretest. If you pass, you do not have to take this lesson.
- Make sure you have the material and equipment to take the lesson.
- Request assistance if you have not taken a printed text TEC lesson before.
- Work through the lesson as often as necessary to master the skills and knowledge covered by this lesson.
- When you complete the lesson, take the Posttest. If you do not pass, take the lesson again.

SUPERVISOR INSTRUCTIONS:

- Administer the Pretest to determine need for the lesson. If only one soldier is being tested, the test may be taken directly from the book, with responses on a separate sheet of paper. If more than one soldier is being tested, reproduce the test for direct use. To pass the test, a soldier must answer 5 of the 6 test items correctly (80%).
- Make sure soldiers have the material and equipment required to complete the lesson.
- Administer the lesson to soldiers who do not pass the Pretest. If possible, administer a performance test to the soldiers upon completion of the lesson.
- Administer the Posttest to soldiers who complete the lesson. Those who do not pass should take the lesson again.

PRETEST/POSTTEST

TEC LESSON 412-051-6782-A

MEASURE LEVEL VALUES FOR
T-3 THEODOLITE
(WISCONSIN METHOD)

This test consists of 6 questions that cover every training objective of the lesson. These questions have a total value of 100 points. When you have completed the test, check your answers against the Pretest/Posttest Answer Key on page 35. If you do not score at least 80 points, you must take the lesson - or take it again if you have already taken it. Write your responses on a separate sheet of paper. Do not write in this book.

1. The plate level on a T-3 is calibrated so that the _____ can be adjusted.
   a. optical plumb
   b. parallax
   c. horizontal observations
   d. vertical observations
2. When calibrating the level vial on a T-3, what should the first vertical circle reading be?
   a. 0°
   b. 90°
   c. 180°
   d. 270°
3. How many minutes is the instrument moved in azimuth when reading both ends of the bubble?
   a. 1
   b. 2
   c. 5
   d. 10

4. What is the drift for the group of readings in T fig 1?
   a. +0.30
   b. +0.02000
   c. −0.02000
   d. −0.30

DESIGNATION _____ DATE _____ 19____

MICROMETER READING (X)	BUBBLE READINGS LEFT	BUBBLE READINGS RIGHT	DIFFERENCES LEFT	DIFFERENCES RIGHT	MEAN DIFF	BUBBLE CENTER	CORR	ADJUSTED CENTER (Y)	R	MARKS
+14	150	387				26 45				
+12	142	379	0 8	0 8	0 8	26 05				
+10	135	371	0 7	0 8	0.75	25 03				
+8	128	363	0 7	0 8	0.75	24 55				
+6	118	354	1 0	0 9	0 95	23 40				
+4	111	349	0 7	0 5	0 60	23 00				
+2	104	340	0 7	0 9	0.80	22 20				
0	99	334	0 5	0 6	0 55	21 65				
−2	89	326	1 0	0 8	0 90	20 75				
−4	82	320	0 7	0 6	0.65	20 10				
−6	75	311	0 7	0 9	0 80	19 30				
−8	69	306	0 6	0 5	0.55	18 75				
−10	63	300	0 6	0 6	0 60	18 15				
−12	58	293	0 5	0 7	0 70	17 55				
−14	51	288	0 7	0 5	0 60	16 95				
+14	153	390	0 3	0 3	0 30	27 15				

FIGURE T-1

5. What reading is given to the recorder for a plate reading of 359° 46′ 00″.0?

   a. +46
   b. +14
   c. −14
   d. −46

6. When reading the bubble ends, to what degree of accurary are the graduations read:

   a. .0
   b. 0.1
   c. 0.2
   d. 0.5

TEC Lesson 412-051-6782-A

INTRODUCTION

Certain errors that are usually overlooked in lower order surveys are not ignored in more precise and accurate surveys (1st order and 2nd order, class I). When the mission objective prescribes it and time permits, the horizontal plate bubble must be calibrated. This is necessary because when the instrument is not level, a true direction is not observed (Fig. 1A and 1B), and the horizontal observations must be adjusted.

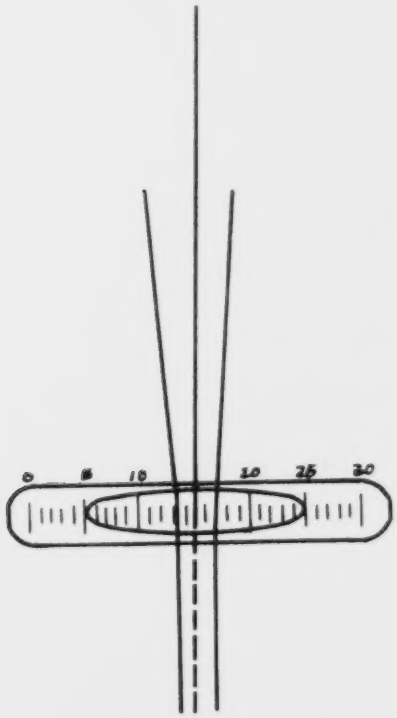


FIGURE 1A

When the instrument is level the observed direction and the true direction are the same.

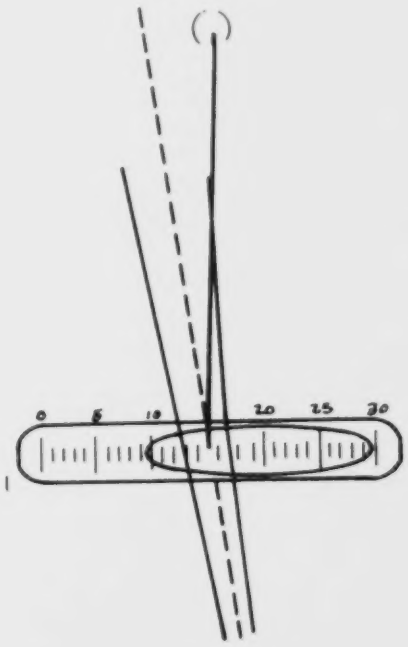


FIGURE 1B

When the instrument is disleveled the observed direction is not the same as the true direction.

The following lesson will show you what your part is as the instrument operator in the calibration of the horizontal plate bubble using the Wisconsin Method.
Refer to Fig. 2 during this lesson to review the parts of the T-3 we will be discussing. There will be (Fig. 2 [and the reference number of the part]) in appropriate places throughout text.

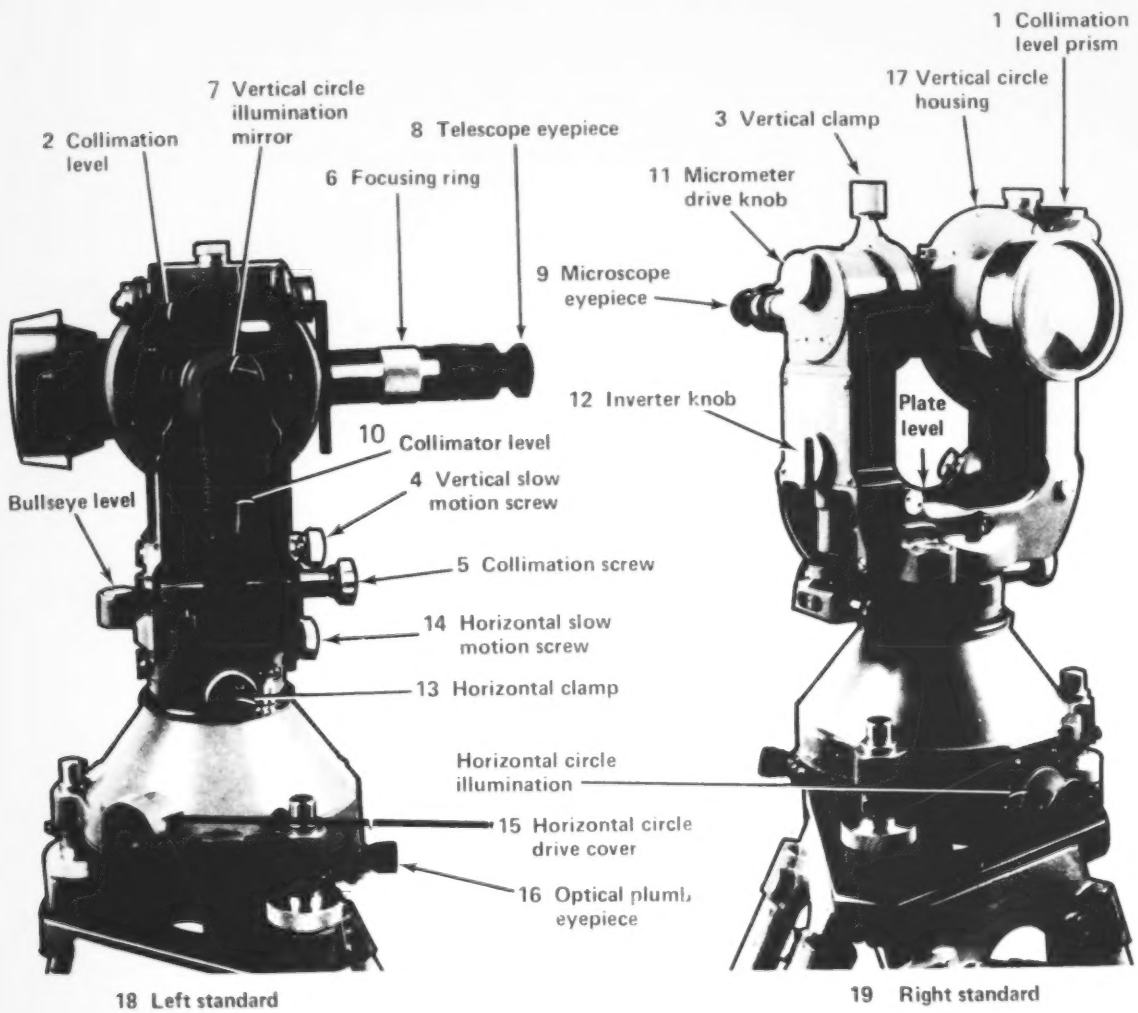


FIGURE 2

OBJECTIVE I. PREPARE INSTRUMENT FOR CALIBRATION

Your first step in preparing the T-3 for calibration is to ensure that the instrument is in adjustment. The item that must be in adjustment is the horizontal bubble. It is not critical that the vertical bubble, the optical plumb or the circular bubble be in adjustment but good survey procedures prescribe it.

If you are not familiar with adjusting an instrument, refer to TEC Lesson 412-051-6751-F, Test and Adjust T-2 Theodolite Part I before continuing with this lesson.

FIGURE 3

A. Level the Instrument

With the bubbles in adjustment, level the instrument near the upper or lower extremities of the foot screws. The reason for this will be explained later in this lesson. You may have to adjust the head of the tripod so that it is as close to level as possible and so that the foot screws will all be extended or depressed the same amount.

Figure 4A shows the tripod head not level, causing the footscrews to be adjusted at different lengths.

Figure 4B shows the tripod head level and the adjusting screws all extended approximately the same amount.

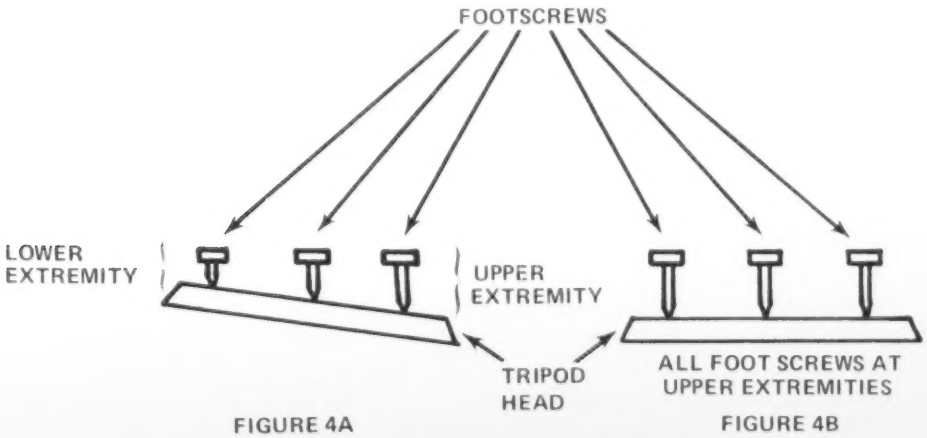


FIGURE 4A FIGURE 4B

Once the instrument is level, turn it in azimuth so that the telescope eyepiece is over one of the foot screws. The instrument should be in the circle left or direct position, but this is not critical. We will refer to the foot screw that the telescope is over as the inclination foot screw. The bubble is now approximately parallel to the other two foot screws (Fig. 5).

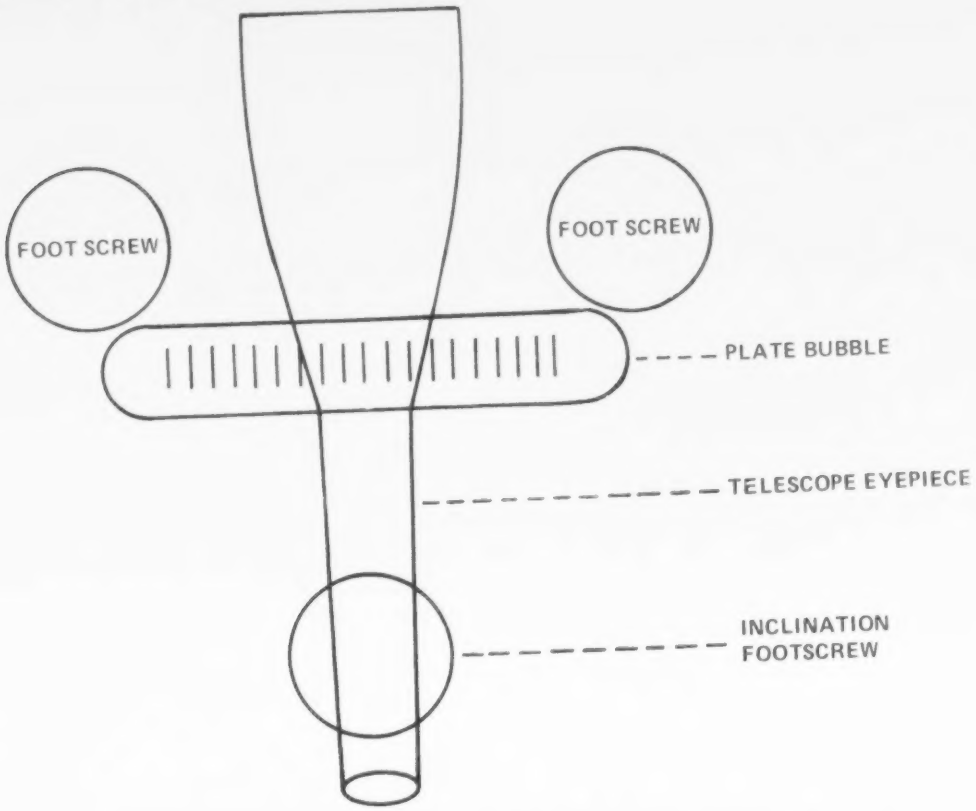


FIGURE 5

Next the telescope eyepiece must be positioned precisely over the inclination footscrew. To do this, the inclination footscrew is lowered, if the instrument was leveled at the upper extremity, or raised if it was leveled at the lower extremity. As the inclination footscrew is raised or lowered, the horizontal bubble is observed for any motion.

If the bubble moves, stop raising or lowering the inclination footscrew and recenter the horizontal bubble by moving the telescope in azimuth with the horizontal slow motion screw (Fig. 2-14).

The direction that you will move the telescope depends on whether the inclination footscrew is being raised or lowered and whether the bubble moves left or right in the vial.

The following two (2) examples happen when the inclination footscrew is being raised. In Fig. 6A, the bubble has moved to the left so the instrument must be turned clockwise to recenter the bubble. In Fig. 6B, the bubble has moved to the right so the instrument must be turned counterclockwise to recenter the bubble.

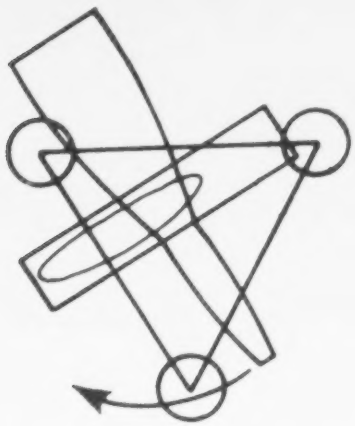


FIGURE 6A

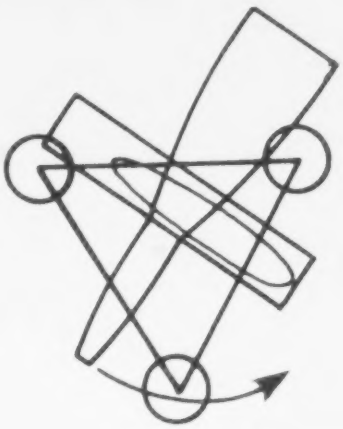


FIGURE 6B

When the inclination footscrew is lowered, the reverse is true. Figure 7 shows both situations. In Fig. 7A, the bubble has moved to the left and the instrument must be turned counterclockwise to recenter the bubble. In Fig. 7B, the bubble has moved to the right and the instrument must be turned clockwise to recenter the bubble.

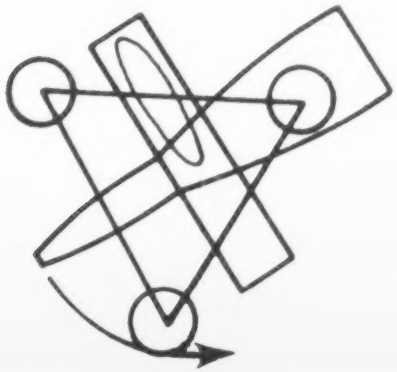


FIGURE 7A

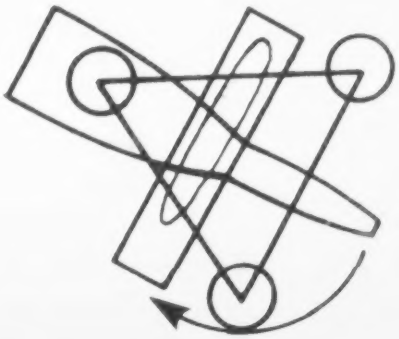


FIGURE 7B

When there is no motion in the horizontal bubble while raising or lowering the inclination footscrew, the telescope is precisely over the inclination footscrew. Then the horizontal plates are set on 0° 00' 00".0 or as close to zero as possible. This will be referred to as the "zero point". The telescope will be moved a number of times during the calibration and must be repositioned to this zero point.

Now that the zero point has been determined the instrument must be releveled. Since only one footscrew was moved it shouldn't be very difficult to relevel the instrument.

B. Measuring Inclination

There is one more procedure that must be completed before the actual observations for the calibration of the horizontal bubble: measuring the inclination.

With the instrument releveled, the telescope must be repositioned precisely at the zero point. To set the telescope at the zero point, the instrument operator turns the instrument in azimuth while looking through the micrometer eyepiece (Fig. 2, 9) until the horizontal plates read close to 0°. When the instrument operator has the telescope in this position, the instrument is locked using the horizontal clamp (Fig. 2,13). The instrument is then set precisely at the zero point using the horizontal slow motion (Fig. 2, 14) screw to set the reading on the plates.

Now that the instrument is set on the zero point, switch the inverter knob (Fig. 2, 12) to the vertical position and adjust the vertical circle illumination mirror (Fig. 2, 7) to give uniform lighting to both sections of the vertical circle and the micrometer scale. Level the collimation level (Fig. 2, 2) with the collimation screw (Fig. 2,5) and read the vertical circle. The circle must read 90° 00' 00". Chances are that the circle does not read 90°. A reading of 90° 00' 00" is obtained by moving the telescope vertically using the vertical slow motion screw, and observing the vertical circle.

Once the vertical plates read as close as possible to 90° 00' 00", the vertical bubble (Fig. 2, 1) is checked to ensure that it is still level by looking through the collimation level prism. The vertical circle is then read to the recorder. This completes the level position reading for the first group.

The next step in measuring the inclination is for the instrument to be inclined a predetermined amount. Since "inclination" is defined as the vertical angle between the horizontal axis of a surveying instrument and the plane of the horizon, you either raise or lower the inclination foot screw to incline the instrument. See Figure 8 for a graphic explanation of inclination.

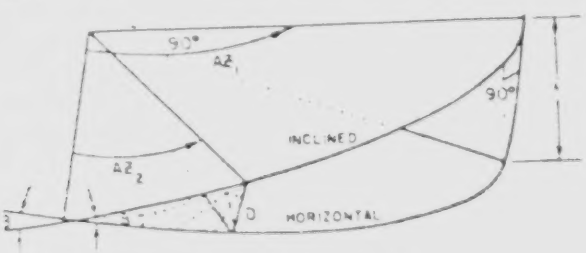


FIGURE 8

Remember when the instrument was being leveled, it was suggested that the instrument be leveled at either the upper or lower extremity of the footscrew. To incline the instrument a specific amount, the trial and error method must be used. After either raising or lowering the inclination footscrew, the vertical bubble is leveled and the vertical plates and micrometer are read. Continue raising or lowering the inclination footscrew, leveling the vertical bubble and reading the plates until the desired vertical angle is reached. NOTE: If the vertical bubble cannot be leveled, a shim, such as a coin, can be inserted between the vertical collimation screw (Fig. 2, 5) and the collimator level (Fig. 2,10).

Once the desired reading/inclination is reached, the vertical plates are put in coincidence and read aloud to the recorder. The desired vertical angle for the first group is either 89° 00′ 00″ or 91° 00′ 00″.

PRACTICE EXERCISE

OBJECTIVE I

1. For what order and class of survey is it required that the horizontal bubble be calibrated?

   a. 2nd order class I
   b. 2nd order class II
   c. 3rd order class I
   d. 3rd order class II

2. What is the recommended position for the footscrews when calibrating a horizontal bubble?

   a. Extended or depressed at different lengths
   b. Extended or depressed the same amount

3. How would you identify the inclination foot screw?

   a. The footscrew the telecope is over
   b. The footscrew that is parallel to the plate bubble

4. What should the vertical plates read for the first position of each group of inclination readings?

   a. 0° 00′ 00″
   b. 45° 00′ 00″
   c. 90° 00′ 00″
   d. 135° 00′ 0″

5. What would you use to incline the instrument?

   a. Vertical clamp
   b. Inclination footscrew
   c. Inverter knob
   d. Horizontal slow motion screw

ANSWERS FOR OBJECTIVE I PRACTICE EXERCISE

1. a. The horizontal bubble must be calibrated for 1st order and 2nd order, class I surveys.

2. b. All footscrews should be extended or depressed approximately the same amount.

3. a. The footscrew the telescope is over is referred to as the inclination footscrew.

4. c. The telescope must be moved vertically until the plates read 90° 00′ 00″ for the first position of each group of readings.

5. b. To incline the instrument either raise or lower the inclination footscrew.

OBJECTIVE II – OBSERVE BUBBLE READINGS FOR THE DETERMINATION OF "d"

Now we are ready to take the actual bubble readings needed to determine the bubble constant "d". The first step is to switch the inverter knob so that the horizontal plates are visible through the micrometer eyepiece. Then unlock the horizontal lock on the intrument and turn the instrument in azimuth to either the left or the right, until the bubble reaches one end of the level vial. Once the bubble reaches either end of the vial, turn the instrument slowly back towards the zero point until both ends of the bubble are under the graduated lines on the vial (Fig. 9).

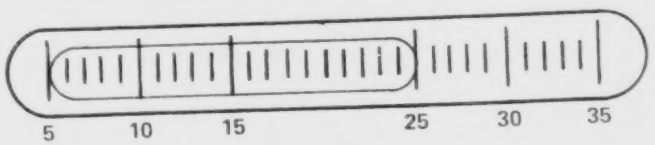


FIGURE 9

When both ends of the bubble are under the graduated lines of the level vial, the next step is to put the telescope on a full minute azimuth. Do this by looking through the micrometer eyepiece and using the horizontal slow motion screw. If the instrument was moved to the left originally, set the instrument on the next lower minute, or the next higher minute, if it was moved to the right. For example, if the instrument was moved to the left and the plates read 359° 46' 43", move the telescope so the plates will read 359° 46' 00". If the instrument was moved to the right the plates read 00° 15' 43", move the telescope so the plates will read 00° 16' 00". If the bubble has moved to the point where one end of the bubble is resting at one end of the vial, or both ends of the bubble are no longer under the graduation of the level vial, then turn the instrument to the next higher or lower minute, as applicable.

The horizontal plates are then read to the recorder. To make it simpler for the recorder, the plates are not read in the usual way. For all reading below 360°, the difference in minutes between 360° and the reading on the plates is given with a minus value; i.e., 359° 46' 00" is read as −14.

For all readings above 360° or 0°, only the minutes are given with a positive value; i.e., 00° 14' 00" is read as +14. After the horizontal plates are read aloud to the recorder, the left and right ends of the bubble are also read aloud to the recorder. The left end of the bubble will always be read first, and the bubble is read to the nearest tenth (0.1). For example, the bubble ends in Fig. 10 would be read at 7.0 and 27.0.

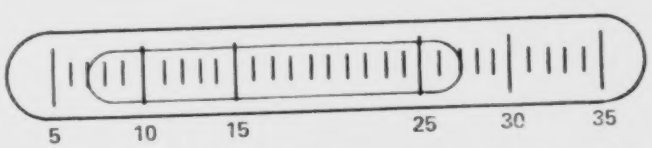


FIGURE 10

After reading both ends of the bubble, the instrument is then turned two (2) minutes in azimuth towards the zero point using the slow motion screw to put the horizontal plates in coincidence. The bubble will now move towards the opposite end of the vial. While waiting for the bubble to settle ten (10) or fifteen (15) seconds, the instrument operator will read the horizontal plates to the recorder, in the same manner as discussed previously. The process of turning the instrument 2' in azimuth, reading the horizontal plates, and the bubble ends is continued until the bubble reaches refusal at the other end of the vial, or until one or both ends of the bubble are no longer under the vial graduations.

Once this point is reached, the telescope is then turned back to the starting azimuth of the set. For example, if the set started at +14 and the final reading is −16, the instrument is then turned back to +14. The horizontal plates and both ends of the bubble are read again. This is done to detect any drift in the bubble so all the bubble centers can be adjusted for the drift.

This completes the "A" portion of the set. A "B" set must be done. The procedure for the "B" portion is the same as the "A" portion. The only difference is that the first reading of the "B" portion is the last reading in the "A" portion prior to checking the bubble for drift.

Upon completion of the "B" portion of the set, including checking for drift, the instrument is then repositioned over the zero or reference point. The inverter knob is switched to the vertical position and the vertical bubble leveled (if needed), and the vertical plates read aloud to the recorder.

This completes the first group for the bubble calibration. At least two (2) more groups are needed. Subsequent groups of inclinations and observations are performed in the same manner, starting with the reading of the vertical bubble in the level position. Since the subsequent inclinations must increase or decrease by 02', the suggested inclinations for the next groups are 88° 58' 00" or 91° 02' 00", and 88° 56' 00" or 91° 04' 00".

PRACTICE EXERCISE

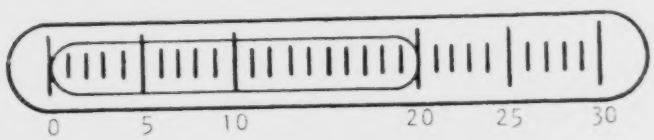
OBJECTIVE II

1. What would you use to put the telescope on a full minute azimuth?

   a. Inverter knob
   b. Horizontal slow motion screw
   c. Inclination footscrew
   d. Vertical slow motion screw

2. What is correct bubble reading (Fig. PE 1)?

   a. 0.0, 20.0
   b. 20.0, 0.0



3. If your starting azimuth was +16, where would you turn the instrument after the final reading of −14?

   a. −16
   b. −14
   c. +14
   d. +16

ANSWERS FOR OBJECTIVE II PRACTICE EXERCISE

1. b, the horizontal slow motion screw is used to put the telescope on a full minute of azimuth.

2. a is the correct bubble reading. Remember the left end of the bubble is read first.

3. d is correct. You would turn the instrument back to the starting azimuth of +16.

OBJECTIVE III CHECK THE FIELD NOTES

Any time a mathematical operation has been performed, or data has been transcribed from one page to another, it must be checked by a second individual, normally the instrument operator. The best qualification for checking the field notes is the ability to record them. For the purposes of this lesson we will assume that you, the instrument operator, do not know how to record for the Determination of the Level Value using the Wisconsin Method. There are two major areas to check. The first is the inclination for each group and the second is the observations for each group.

A. Check Inclination Computations

As stated before, the first area to check is that the inclination (i) for each group has been determined (computed) correctly. The mean (average) of each pair of inclined positions is checked. This is done by adding up the pair and dividing the results by two. The i for each group is then determined by either subtracting the mean inclined position from the level position or the level position from the mean inclined position, and multiplying the results by two, since the bubble being calibrated is on a T-3 and only gives 1/2 the vertical angle.

Figure 11 shows:

(1) the mean inclination for positions A and B of group 1,
(2) the difference between the level position and the mean of the inclined positions, and
(3) the inclination (i).

30

BUBBLE CALIBRATION (WISCONSIN METHOD)

DESIGNATION DETM of INCL (w) DATE 6 MAY 19 85

GP - POS	VERTICAL ANGLE °	'	"		
1 LEVEL	90	00	02 2		
1A INCL	89	01	0 2		90°
1B INCL	89	01	04 2		89°
MN INCL	89	01	05.2	(1)	00°
					01°

X SP/S JONES WEATHER CODE CALM CLEAR
4 SP/S MARTIN INST. WILD T-3 134827

00°	02" 2			
01°	05" 2			
58°	57" 0 (2)	= 1° 57' 54" 0		
X	2			
57°	54" 0 (3)			

FIGURE 11

Therefore on the first page 3 items are checked for each group that is observed.

B. Check observations

The second major area to check is the observations of individual groups. In this area there are five items that are common to all groups observed.

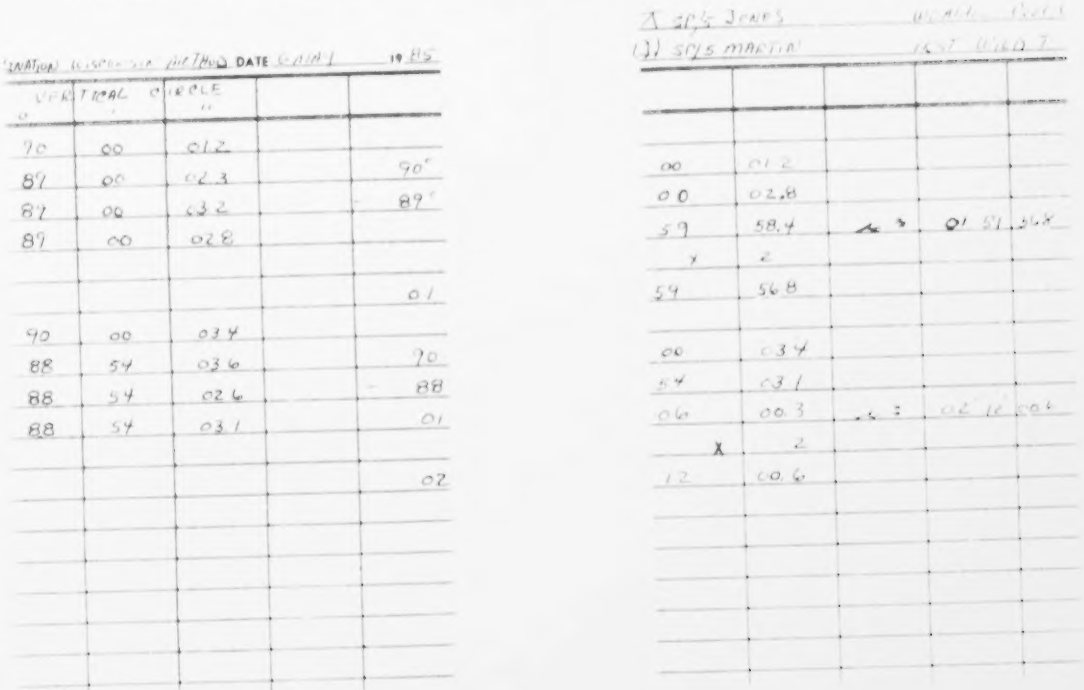
Check: 1. the inclination
2. the differences in the left ends of the bubble
3. the differences in the right ends of the bubble
4. the mean differences
5. the bubble center.

These five items (Figure 12) will now be explained in more detail.

FIGURE 12

1. Check Inclination Transcription

Each group of readings has an inclination that must be used in the computation of "d". This check is probably the simplest to do. It is only a matter of making sure that the inclination for each group has been transcribed from the page where the inclination was computed (Figure 13), to the page where it will be used.



°	VERTICAL '	CIRCLE "		
90	00	01.2		
87	00	02.3		90°
87	00	03.2		89°
89	00	02.8		
				01
90	00	03.4		
88	54	03.6		90
88	54	02.6		88
88	54	03.1		01
				02

00	01.2			
00	02.8			
59	58.4			01 59 56.8
x	2			
59	56.8			
00	03.4			
54	03.1			
06	00.3			02 12 00.6
x	2			
12	00.6			

FIGURE 13

For example, an error in transcription would be, if the inclination for group 2 is 2° 12′ 00″.6 and it is transcribed on the page for group 1A (Figure 14A). Another example of a mistake would be that if the inclination for group 1 is 1° 59′ 56″.8 but the number

DESIGNATION VALUE WISCONSIN METHOD GP 1-A DATE 6 MAY 19 85

MICROMETER READING (X)	BUBBLE READINGS LEFT	BUBBLE READINGS RIGHT	DIFFERENCES LEFT	DIFFERENCES RIGHT	MEAN DIFF
+14 16	16.2	40.0			
+12 14	15.4	39.1	0.8	0.9	0.85
+10 12	14.9	38.6	0.5	0.5	0.50
+8 10	14.2	38.0	0.7	0.6	0.65
+6 8	13.5	37.2	0.7	0.8	0.75
+4 6	12.9	36.6	0.6	0.6	0.60
+2 4	12.1	35.8	0.8	0.8	0.80
0 2	11.3	35.0	0.8	0.8	0.80
-2 0	10.6	34.3	0.7	0.7	0.70
-4 -2	10.0	33.7	0.6	0.6	0.60
-6 -4	9.1	33.0	0.9	0.7	0.80
-8 -6	8.6	32.3	0.5	0.7	0.60
-10 -8	7.9	31.7	0.7	0.6	0.65
-12 -10	7.2	31.0	0.7	0.7	0.70
-14 -12	6.7	30.5	0.5	0.5	0.50
-16 -14	6.0	29.8	0.7	0.7	0.70
-18 -16	5.3	29.1	0.7	0.7	0.70
+14	16.2	40.0	0.0	0.0	0.0

A SP/S JONES WEATHER Cool CALM CLEAR

B SP/S MARTIN INST WILD T-3 19487

BUBBLE CENTER	COR	ADJUSTED CENTER	REMARKS		
28.10			i = 02°	12′	00.6
27.25					
26.75					
26.10					
25.35					
24.75					
23.95					
23.15					
22.45					
21.85					
21.05					
20.45					
19.80					
19.10					
18.60					
17.90					
17.20					
28.10					

FIGURE 14A

transcribed on the observation page is 1° 59' 58".6 (Figure 14B).

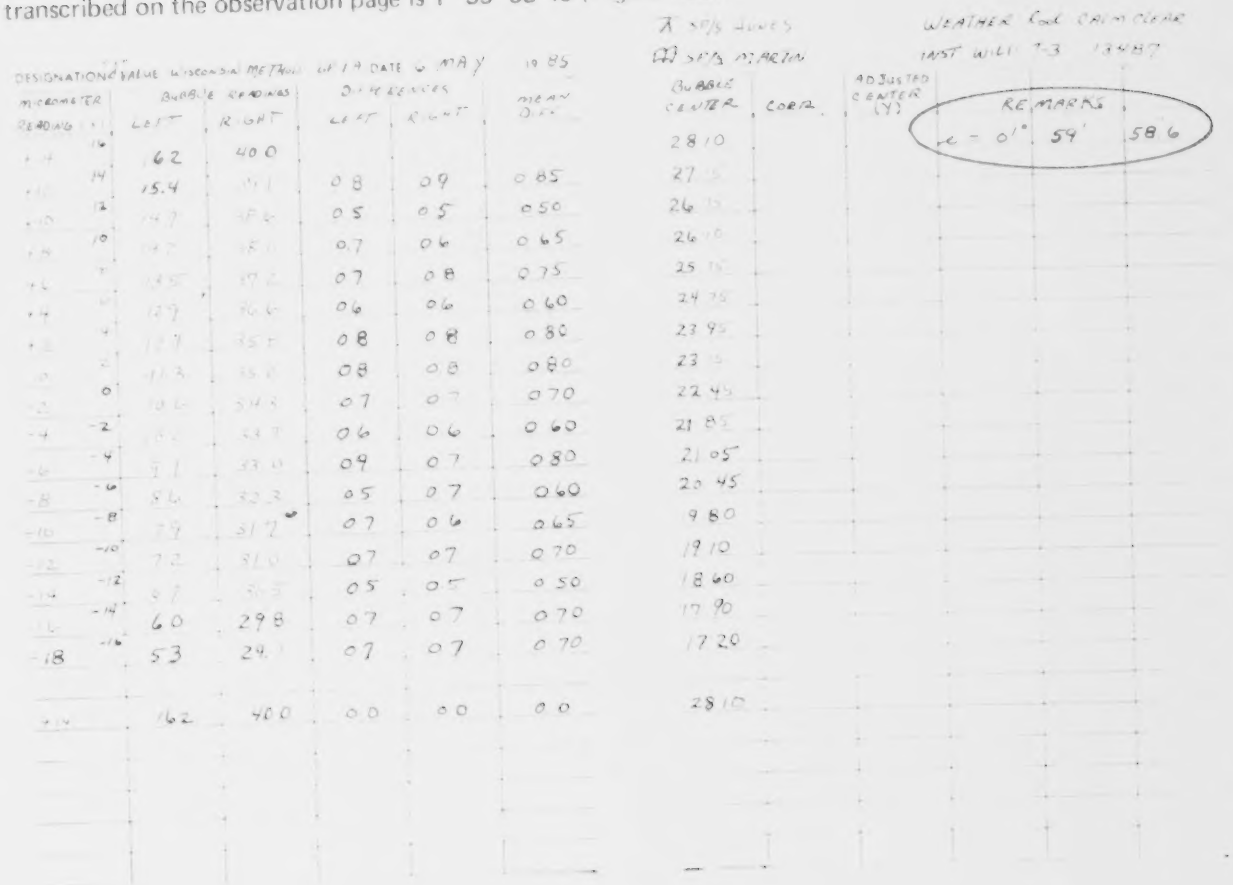


FIGURE 14B

2. and 3. Check Left and Right Differences for Correctness

The next two items may either be done separately or concurrently. That is, all the left end differences can be checked and then all the right end differences, or you can alternately check the left and right end differences. Figure 15 shows that portion of the recording page with which we will be concerned.

BUBBLE CALIBRATION
WISCONSIN METHOD
DESIGNATION GROUP 1 - A DATE 6 MAY 1985

J SP/S JONES
M SP/S MARTIN

MICROMETER READING (X)		BUBBLE READINGS LEFT	RIGHT	DIFFERENCES LEFT	RIGHT	MEAN DIFF	BUBBLE CENTER CORR	ADJUSTED CENTER
+20	17	(14.2)	38.0				26.10	
+18	15	(14.0)	37.9	(02)	01	015	25.95	
+16	13	13.8	37.6	02	03	025	25.70	
+14	11	13.3	37.1	05	05	050	25.20	
+12	9	13.0	36.8	03	03	030	24.90	
+10	7	12.5	36.2	05	06	055	24.35	
+8	5	12.2	36.1	03	01	020	24.15	
+6	3	11.8	35.7	04	04	040	23.75	
+4	1	11.3	35.2	05	05	050	23.35	
+2	-1	10.8	34.9	05	03	040	22.95	
0	-3	10.8	34.7	02	02	020	22.75	
-2	-5	10.3	34.1	05	06	055	22.20	
-4	-7	10.1	34.0	02	01	015	22.05	
-6	-9	9.9	33.7	02	03	025	21.80	
-8	-11	9.5	33.2	04	05	045	21.35	
-10	-13	9.0	32.9	05	03	040	20.95	
-12	-15	8.9	32.7	01	02	015	20.80	
-14	-17	8.4	32.1	05	06	055	20.25	

FIGURE 15

There are no differences for the left and right ends of the bubble to check for the first bubble reading of any group. All subsequent observations have differences that have to be checked, and these readings may be lower or higher than the first bubble reading. For example since (Fig. 15) the second left bubble reading is lower it is subtracted from the first or previous left bubble reading and the difference is then compared to what is recorded in the appropriate difference column. The same procedure is followed for the right bubble readings, comparing that difference to what is recorded in the right difference column. In Fig. 15 the second left bubble reading (14.0) is subtracted from the first or previous left bubble reading (14.2).

$$\begin{array}{r} 14.2 \\ -14.0 \\ \hline 0.2 \end{array}$$

The answer 0.2 compares with the 0.2 recorded in the differences left column.

This procedure is continued for each succeeding reading, always subtracting the next reading from the immediately preceding reading until the last reading in the set is reached.

If the second bubble reading was higher than the first then you would subtract the first reading from the second and continue this procedure until the last portion is compared.

The final observation recorded on the page is used to determine the drift. The difference between this observation and the initial observation must be determined. This is done by subtracting the lower reading from the higher. Drift will be covered further in TEC Lesson Record and Compute the Level Values of a T-3 (Wisconsin Method).

4. Check Mean Differences for Correctness

After checking all the differences of the bubble ends, the mean difference column is the next item that you, as the instrument operator, must check. The mean difference is the average of each pair of left and right differences. For example, in Figure 16 the first pair of differences is 0.2 to 0.1.

BUBBLE CALIBRATION WISCONSIN METHOD GROUP 1-A

DATE 6 MAY

		BUBBLE READINGS		DIFFERENCES		MEA		
		LEFT	RIGHT	LEFT	RIGHT	DIFF		
+20	5	14.2	38.0				26.10	
+18	3	14.0	37.9	0.2	0.1	0.15	25.95	
+16	2	13.8	37.6	0.2	0.3	0.25	25.70	
+14	0	13.3	37.1	0.5	0.5	0.50	25.20	
+12	1	13.0	36.8	0.3	0.3	0.30	24.90	
+10	7	12.5	36.2	0.5	0.6	0.55	24.35	
+8	5	12.2	36.1	0.3	0.1	0.20	24.15	
+6	9	11.8	35.7	0.4	0.4	0.40	23.75	
+4	1	11.5	35.2	0.3	0.5	0.40	23.35	
+2	-1	11.0	34.9	0.5	0.3	0.40	22.95	
0	-3	10.8	34.7	0.2	0.2	0.20	22.75	
-2	-5	10.3	34.1	0.5	0.6	0.55	22.20	
-4	-7	10.1	34.0	0.2	0.1	0.15	22.05	
-6	-9	9.9	33.7	0.2	0.3	0.25	21.80	
-8	-11	9.5	33.2	0.4	0.5	0.45	21.35	
-10	-13	9.0	32.9	0.5	0.3	0.40	20.95	
-12	-15	8.9	32.7	0.1	0.2	0.15	20.80	
-14	-17	8.4	32.1	0.5	0.6	0.55	20.25	

FIGURE 16

By adding: 0.2
0.1
0.3

and by dividing by 2:

$$\frac{0.3}{2} = 0.15$$

you obtain the mean difference.

5. Check the Bubble Center

The bubble center of the first observation is the mean of the bubble left and bubble right readings which again is obtained by adding the left and right ends of the bubble and dividing the result by two. This answer should agree with the recorded value in the bubble center column. For example, in the first bubble observation (Fig. 17) we add the left end of the bubble and the right end of the bubble and divide by two.

BUBBLE S/[illegible] FROM 1-A — DATE 6 MAY — SP/S JONES / SP/S MARTIN

MICROMETER READING (X)		BUBBLE READINGS LEFT	RIGHT	DIFFERENCES LEFT	RIGHT	MEAN DIFF	BUBBLE CENTER CORR	ADJUSTED CENTER (X)
+20	17	14.2	38.0				26.10	
+18	15	14.0	37.9	0.2	0.1	0.15	25.95	
+16	13	13.8	37.6	0.2	0.3	0.25	25.70	
+14	11	13.3	37.1	0.5	0.5	0.50	25.20	
+12	9	13.0	36.8	0.3	0.3	0.30	24.90	
+10	7	12.5	36.2	0.5	0.6	0.55	24.35	
+8	5	12.2	36.1	0.3	0.1	0.20	24.15	
+6	3	11.8	35.7	0.4	0.4	0.40	23.75	
+4	1	11.5	35.2	0.3	0.5	0.40	23.35	
+2	-1	11.0	34.9	0.5	0.3	0.40	22.95	
0	-3	10.8	34.7	0.2	0.2	0.20	22.75	
-2	-5	10.3	34.1	0.5	0.6	0.55	22.20	
-4	-7	10.1	34.0	0.2	0.1	0.15	22.05	
-6	-9	9.9	33.7	0.2	0.3	0.25	21.80	
-8	-11	9.5	33.2	0.4	0.5	0.45	21.35	
-10	-13	9.0	32.9	0.5	0.3	0.40	20.95	
-12	-15	8.9	32.7	0.1	0.2	0.15	20.80	
-14	-17	8.4	32.1	0.5	0.6	0.55	20.25	

FIGURE 17

By adding:

$$\begin{array}{rl} 14.2 & \text{– left end of bubble} \\ +38.0 & \text{– right end of bubble} \\ \hline 52.2 & \end{array}$$

and dividing by 2:

$$\frac{52.2}{2} = 26.1$$

This compares with the recorded value. A secondary check is to take the previous bubble center and add or subtract the new difference. Each subsequent bubble center is checked in the same manner.

NOTE: As in all other survey procedures, after checking field notes the instrument operator initials the bottom of the page.

PRACTICE EXERCISE

OBJECTIVE III

1. When checking field notes, which computation would you check first?

   a. Inclination
   b. Observations

2. Why would you multiply the i for each group by 2?

   a. To obtain the mean of 2 groups
   b. Because the T-3 gives 1/2 the vertical angle

3. If your left differences check out correctly, you do not have to check the right differences too.

   a. T
   b. F

4. If the second observation is lower than the first you would:

   a. Subtract the second from the first
   b. Subtract the first from the second

5. The mean of the left and right bubble reading should agree with:

   a. The mean of the second observation bubble reading
   b. The bubble center recorded value
   c. The mean difference recorded value

ANSWERS FOR OBJECTIVE III PRACTICE EXERCISE

1. a. First you would check inclination computations.

2. b. Since the bubble being calibrated is on a T-3 and only 1/2 the vertical angle is given, you must multiply by 2.

3. b. False. You can check all the left differences first and then the right differences or alternate checking left and right but both sides must be checked.

4. a. You subtract the lower observations from the higher.

5. b. The mean of the left bubble reading should agree with the recorded value in the bubble center column.

SELF EVALUATION

OBJECTIVE I

1. What must be in adjustment on a T-3 Theodolite before determining the level constant using the Wisconsin Method?

   a. Horizontal bubble
   b. Circular bubble
   c. Vertical bubble
   d. Optical plumb

2. What control is used to set the telescope precisely over the zero point?

   a. Vertical slow motion
   b. Vertical clamp
   c. Inclination footscrew
   d. Horizontal slow motion

SELF EVALUATION

OBJECTIVE II

1. How many minute(s) in azimuth are there between bubble readings?

   a. 0.5
   b. 1
   c. 2
   d. 4

2. In Fig SE-1, what is the correct bubble reading?

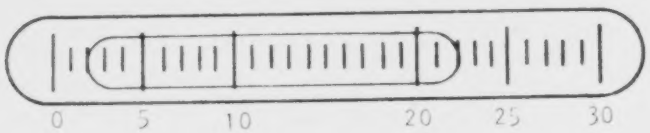


FIGURE SE-1

   a. Right end 22 left end 2
   b. Left end 2, right end 22

SELF EVALUATION

OBJECTIVE III

Refer to field notes in SE Figs. 2 and 3.
Check them and make corrections as needed

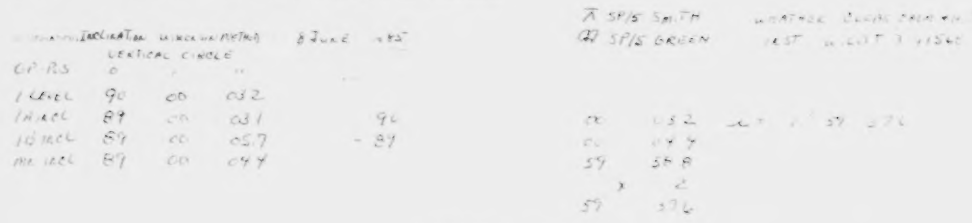
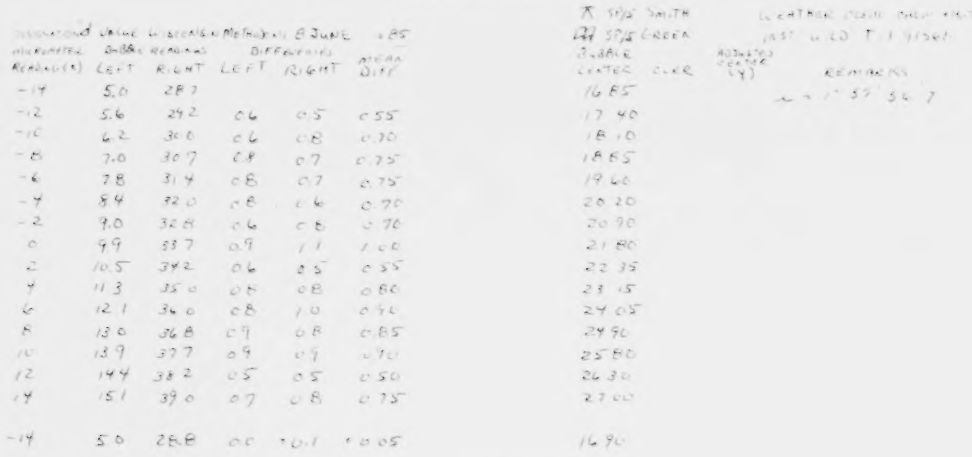


FIGURE SE-2



Check your corrections in SE Fig. 4. FIGURE SE-3

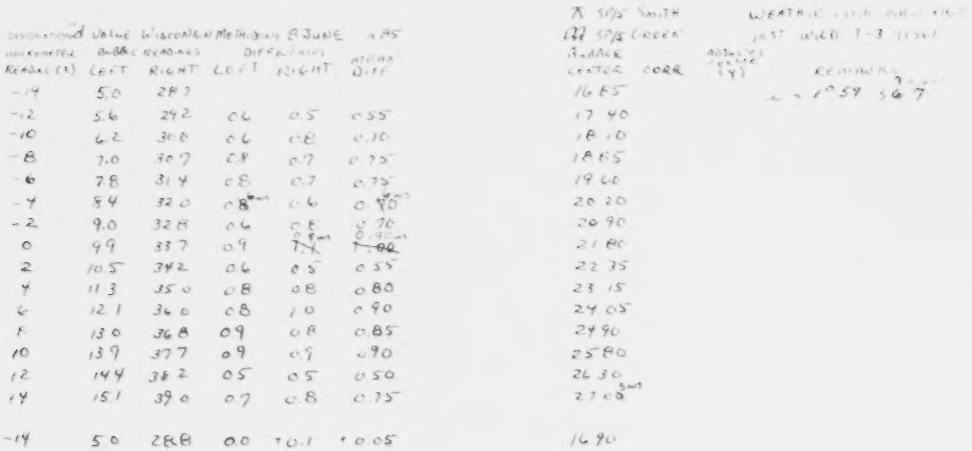


FIGURE SE-4

ANSWERS TO SELF-EVALUATION

OBJECTIVE I

1. a. The horizontal bubble must be in adjustment before determining the level constant.

2. d. The horizontal slow motion control (screw) is used to put the telescope precisely over the zero point.

SELF-EVALUATION OBJECTIVE II

1. c. The bubble readings are read at 2 minute increments.

2. b. The left end of the bubble is always read first.

SELF-EVALUATION OBJECTIVE III

There are no corrections to the inclination page. The errors to be corrected are shown in Fig. SE-4.

PRETEST/POSTTEST ANSWER KEY

This is the answer key to the pretest for lesson 412-051-6782-A. Each soldier must correctly answer 5 of the 6 total test items to pass this test. If he gets less than 5 items correct, he should take/retake this lesson.

1. c

2. b

3. b

4. a

5. c

6. b